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The Solar Vortex: Electric Power Generation using Anchored, Buoyancy-Induced Columnar Vortices

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Naturally-occurring, buoyancy-driven columnar vortices ("dust devils") that are driven by the instability of thermally stratified air layers and sustained by the entrainment of ground- heated air, occur spontaneously in the natural environment with core diameters of 1-50 m and heights up to 1 km. These vortices convert low-grade waste heat in the air layer overlying the warm surface into a solar-induced wind with significant kinetic energy. Unlike dust devil vortices that are typically free to wander laterally, the Solar Vortex (SoV) is deliberately triggered and anchored within a cylindrical domain bounded by an azimuthal array of stationary ground-mounted vertical vanes and sustained by continuous entrainment of the ground-heated air through these vanes. The mechanical energy of the anchored vortex is exploited for power generation by coupling the vortex to a vertical-axis turbine. This simple, low-cost electric power generating unit is competitive in cost, intermittency, and capacity factor with traditional solar power technologies. The considerable kinetic energy of the vortex column cannot be explained by buoyancy alone, and the fundamental mechanisms associated with the formation, evolution, and dynamics of an anchored, buoyancy-driven columnar vortex were investigated experimentally and numerically with specific emphasis on flow manipulation for increasing the available kinetic energy and therefore the generated power. These investigations have also considered the dependence of the vortex scaling and strength on the thermal resources and on the flow enclosure in the laboratory and in the natural environment. Preliminary outdoor tests of a two-meter scale prototype successfully demonstrated the ability to engender and anchor a columnar vortex using only solar radiation and couple the flow to a vertical axis wind turbine. A kilowatt-scale outer door prototype will be tested during the summer of 2015.

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